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ABSTRACT

A study of speakers of a range of English dialects was conducted to investigate some influences on the pattern of phonetic final devoicing of phonologically voiced fricatives and affricates. With the help of spectrographically examined tape-recorded speech derived from sociolinguistic interviews of the subjects, the study examined seven English dialects and a small amount of data from two non-native-English speakers. It was found that the differences among speakers in overall likelihood of devoicing did not appear to be attributable to regional dialect differences. It was concluded that the final devoicing of phonologically voiced fricatives is a pan-English phenomenon. (GLR)

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Final Devoicing of Fricatives in English

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1 Introduction

Although "final devoicing" in German is the most widely known process of Germanic phonology, little attention has recently been paid to a pattern of phonetic final devoicing in perhaps the most prominent of Germanic languages, namely, English. This study is concerned not with phonological neutralization,[1] but with the segmental conditioning of a particular low-level phonetic rule, according to which actual voicing is interrupted in phonologically voiced sounds.

In many English dialects underlyingly voiced final obstruents frequently are often phonetically voiceless: the fricatives have no concurrent glottal pulsing, and the stops have a voiceless release. The term, "voiced", is here meant in its normal, literal sense; that is, it is applied to sounds which have concurrent glottal pulsing. I will use the phrase, "phonologically voiced," when I don't wish to imply actual voicing.[2] Phonologically voiced fricatives in word-final (and sometimes word-internal but phonotactically syllable-final) position are phonetically "devoiced" in a systematic probabilistic pattern.

This study examines the conditioning of the pattern of "final devoicing of fricatives." This phrase requires clarification in this context. First, "final" could mean "word-final", "syllable-final", or "utterance-final". Since utterance-final segments are always also syllable- and word-final, utterance-final segments are implicitly included when word-final or syllable-final segments are referred to. The phonologically voiced fricatives examined here are mostly word-final, though the rare word-internal tokens that are phonologically syllable-final[3] are also included.

As in other studies of fricative devoicing, a "devoiced" fricative is here defined as one in which voicing stops before frication stops. Thus a fricative which is devoiced during only a part of its duration is counted as devoiced. Also, a segment which corresponds to a phonologically voiced fricative that does not appear to contain either voicing or frication is not classified as devoiced, since frication does not continue in the absence of voicing.[4]

[1] Phonological final devoicing seems to occur in many languages, not only in German, but also Polish, Russian, Turkish, Catalan, Old Spanish and Old French, and no doubt many other languages.

[2] English /d/, for example, is often called a voiced stop, but in utterance-initial position in English, /d/ typically lacks voicing during closure. The difference between /d/ and /t/ (in utterance-initial position) is not a difference in voicing during closure, but of aspiration after closure. To avoid distortion or error, I will refer to /b,d,g,v,ð,z,j/ as "phonologically" voiced, since actual voicing is not necessarily implied.

[3] For example, the /z/ in the surname "Hazlett". Ambisyllabic segments, as the /z/ in "misery" were excluded.

[4] It may be objected that since utterances are often followed by in-breaths, it is conceivable that confusion

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Finally, the voiced affricate, /j/ as in "judge" is included in the study; it contains a fricative segment and also participates fully in the pattern of devoicing as we will see. This study therefore considers both fricatives and affricates, both of which contain a fricative segment.

Our topic, then, is (word-, syllable-, and redundantly, utterance-) final (partial or complete) devoicing of fricatives (and affricates). This topic is just one facet of the larger phenomena of voicing changes, in which fricatives, stops, and even vowels and other segments either lose or gain actual voicing, often but not always in assimilatory environments. It would certainly be useful to get a full picture of all these changes to see if they constitute one or many linguistic processes. All these phenomena may be noticed occurring repeatedly in any few minutes of naturally spoken English; only the seemingly most prominent subclass is examined here.

Numerous investigators have noticed the devoicing of phonologically voiced fricatives,[5] of whom I will discuss just three. This phenomenon was noticed at least as early as 1921, when Sapir (1921:43) wrote, "Probably not one English speaker in a hundred has the remotest idea that ... the final *s* of a word like *heads* is not the full buzzing sound of the *s* in such a word as *please*." In 1969, Lisker, Abramson, Cooper and Schvey, in a transillumination study, found a very low frequency (3%) of devoicing of voiced fricatives occurring between phonologically voiced segments. Finally, most relevant to this study, Haggard (1978) published a most valuable study of devoicing of fricatives in British English, the results of which are in many ways confirmed by those of this study. Haggard studied not only word-final but also word-medial and word-initial fricatives, and found considerable devoicing in not only final but also medial and initial positions in reading-style speech of British speakers.

2 Methods

Methods of studying fricative devoicing vary. The essential problem is to establish if a particular fricative is devoiced or not. In the Lisker et al. 1969 study, this question was answered by using transillumination, which measures glottal opening by the amount of light transmitted through the glottis.[6] In Haggard's devoicing study, the throat accelerometer or microphone was used to good effect. The throat microphone gives a fairly clear picture of vocal fold movements, and while the exact degree of glottal opening may be somewhat obscured, periodicity of vocal fold movements is quite well represented, making this an appropriate method of studying devoicing. In either the transillumination or the throat microphone methods, the glottal signal is compared with the output speech signal, and if frication is present after periodicity in the glottal signal ceases, the token is classified as devoiced.

While laboratory methods give fairly direct measures of glottal activity, they are subject to certain criticisms. The basic, vernacular, phonetic production system undergoes considerable distortion under laboratory conditions. Certainly if a variable is subject to

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may arise between (egressive) final voiceless frication and (ingressive) breath-noise. I have not found this to be a problem in practice.

[5] Final devoicing of fricatives is mentioned or described in Hughes, et al., 1954; Gimson, 1962:174; Delattre, 1965; Selkirk, 1972; Baugh, 1983; and others.

[6] Transillumination is discussed more fully in Malécot & Peebles, 1965.

style-shifting in formal or monitored speech situations, as are many phonetic variables, it will be difficult to discover the natural, vernacular pattern of that variable in the highly monitored setting of the phonetics laboratory. To counter such criticisms, it is worth investigating whether less disruptive methods exist which detect devoicing with reasonable accuracy. An accurate measure of devoicing may be found which uses tape-recordings of natural conversations, in which linguistic behavior more closely approaches the vernacular linguistic system.[7]

Indeed, it is possible to detect voicing with a reasonable degree of confidence by spectrographically examining tape-recorded speech. Spectrograms are fairly good at representing glottal periodicity. In the narrow-band view, the amplitude of the fundamental and other harmonics may be tracked. A 10db dropoff of harmonic energy is a fair measure of the end of voicing (K. Stevens, p.c.). In the broad-band spectrogram view, periodic vertical spikes especially in the low frequencies more directly represent glottal opening and closing. This spiking is often revealed only at certain settings of the spectrogram level and dynamic range. Using the Waves+ speech analysis system,[8] the level and dynamic range of a spectrographic display on a computer graphics terminal may be rapidly and continuously varied by hand, so that if this regular spiking is present in the spectrogram at any level or dynamic range, it may be quickly and easily found.

Finally, fricative devoicing in tape-recorded speech may be impressionistically classified by a trained phonetician. This is the method used in this study. The difficulty with this method is that others need not believe that phonetician's subjective judgements.

How much can you trust my ears? An attempt was made to answer this question. For two of the speakers in the study, 45 and 50 tokens of final phonologically voiced fricatives were classified impressionistically as having a voiceless section or not. Wide-band and narrow-band spectrograms of the relevant segments were then made and classified as discussed above. For the first speaker, 42 out of 45 tokens were correctly classified impressionistically, with one mistaken "devoiced" classification, and two mistaken "not devoiced" classifications. For the second speaker, all 50 tokens were classified correctly, where "correct" here means, "consistent with the independent visual classification of spectrograms of that token." So the impressionistic binary classifications which form the data of this study may be estimated to be perhaps as much as 97% correct.

3 Dialects Studied

Many American phoneticians refer to an imaginary dialect called "General American English" (henceforth GAE). While such a dialect is conceptually possible, its existence, much less its linguistic or phonetic uniformity, has not been established. On the contrary, in traditional dialectology this dialect was shown not to exist. In 1949, Hans Kurath stated: "The widely accepted assumption that there is a 'General American' type of English proves to be equally unfounded in fact; no Southerner or New Englander would ever have made such a generalization."(1949:vi) He established Northern, Midland, and Southern as three

[7]The vernacular is doubly defined as the style of speech which is acquired in youth and adolescence, and as the unmonitored speaking style(s). In this style, the least attention is paid to speech, so that the speaker is thinking about what she is saying rather than how she is saying it.

[8]Developed at A.T. & T. Bell Laboratories, and commercially available from Entropic Speech, Inc., Washington D.C.

major, distinct dialects of (Eastern) American English: "*There is an extensive Midland speech area that lies between the traditionally recognized 'Northern' and 'Southern' areas.*"(1949:v)(emphasis in original.) Further research has confirmed and fleshed out this overall picture (see, eg., Labov, 1990), showing further that phonetic diversification of dialects is increasing. Even relatively local subdivisions of these larger dialects, down to the level (at least) of large cities, may differ in crucial ways when phonetic behavior is studied.[9]

Phonetic studies of this supposed dialect are flawed. Subjects may be from Texas or New York or some other unspecified part of "General America", so it is not clear what exactly is the geographical region being studied. If the term "General American English" is taken to imply some uniformity of the dialect referred to, then the studied GAE dialect is assumed to be similar to other GAE dialects. This assumption is untenable. Dialect differences have been found wherever they have been searched for. Therefore it is unreasonable to assume that the GAE dialect under study is the same as any other GAE dialect in the relevant ways.

The solution to this difficulty is two-fold. First, phoneticians should abandon the concept of "General American English", unless or until this dialect is located in social and geographic space and shown to be phonetically uniform. Second, phonetic studies should include a mention of the geographic origin (most significantly during childhood and adolescence) of the speakers studied.[10]

This study attempts to examine phonetic final devoicing in "English". It therefore must make some attempt to examine a wide variety of English dialects, with which it may be possible to document rather than speculate about dialect uniformity. This study includes vernacular speakers of each of Labov's vowel-based "Three Dialects of English" and also certain other dialects. Speakers are natives of Southern California (Low-Back-Merged), Chicago (Northern Cities), Alabama (Southern), England, and one black and two white Philadelphians, for a total of 7 speakers of a range of English dialects. A small amount of data from two non-native-English speakers was also included to provide some idea of the pattern of final devoicing in another language (Hindi, in this case), and in non-natively spoken English.[11] While numerous quite distinct dialects are omitted from this study (Australian, Scots, Irish, South African, (East) Indian, and Canadian dialects among others), the conversational speech of the speakers chosen nonetheless covers a broad range of dialects.

Since a small number of speakers of each dialect (usually just one) is studied here, we cannot infer that each speaker is characteristic of their social class and region. However, this small sample can be used to see if the pattern is shared across dialects.

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[9]Paying attention to geographic details still ignores the striking social subdivisions within urban communities which are also phonetically highly differentiated. For example, in many U.S. cities the major social division that is correlated with linguistic and phonetic differences is between (most) blacks and (most) whites. Where phonetic change is in progress, the speaker's age may be systematically related to variations in phonetic details. Gender is another important variable, which in contrast to age and ethnicity has had more attention paid to it in laboratory studies. Phonetic differences across these social dimensions have been found in vowel formant-frequencies(Labov, Yeager, and Steiner, 1972), in consonant cluster articulation (Guy, 1980), pitch range (Tarone, 1973) etc.

[10]Age, gender, and information about social background, such as their social class, race and/or ethnicity would also be helpful in locating the particular kind of speech being studied.

[11]The speaker is a Romanian immigrant to the U.S., who began speaking English at age 16.

4 Data Analysis

Speaker were tape-recorded in a sociolinguistic interview.[12] From the middle of each tape, roughly a hundred consecutive tokens — though two speakers had twice that many — of phonologically voiced fricatives were found. Fricative tokens were excluded only if the word containing the token and thus the underlying fricative phoneme itself was not positively identifiable.

Each token was classified five ways, namely, the fricative phoneme itself, the preceding phoneme, the following phoneme, the speaker, and whether it was devoiced or not.

Relevant phonetic factors that were not examined include stress of preceding and following syllables, phonetic realization of the underlying phonemes, and duration of the fricative and of preceding segments. Also, both word-final and non-word-final, syllable-final tokens were treated together, since exclusively syllable-final fricatives were infrequent. The morphological source of the voiced fricative (including the English nominal-plural /-z/, possessive /-z/, verbal-singular /-z/, contracted form of "is" or "has", etc.) was not examined, although this is to be studied in further research. Finally, speech-styles were not distinguished; style varied between "careful" and "casual" speech. "Careful" speech is unrehearsed, interactive dialogue under the constraints of an interview situation. "Casual" speech is constituted by narratives (cf., Labov & Waletsky, 1968) and speech not directed to the interviewer. "Casual" speech approaches shows the least influence of conscious monitoring of speech. This is the closest an interview can get to the vernacular, least-monitored style.

The tokens were analyzed using the multivariate statistical techniques known as variable-rule analysis.[13] This multivariate statistical methodology was discussed originally in Cedergren & Sankoff (1974); recent versions are summarized in Sankoff & Labov (1979) and Guy (1980). A discussion of advanced techniques is to be found in Guy (1986). In summary, the variable-rule model assumes that the probability of a rule applying in an environment characterized by factors a,b,..,d, with one of these chosen from each of a number of independent factor-groups A,B,..D, is the product:

$$P(\text{application} \mid \text{factors } a,b,..d) = P_{input} \times \frac{P_a}{1-P_a} \times \frac{P_b}{1-P_b} \times \cdots \times \frac{P_d}{1-P_d},$$

where the P_i are numbers between 0 and 1 associated with the individual factors, i, loosely called "probabilities". Given the assumption of independence of factor-groups, an iterative procedure may be used to determine the best-fitting model; ie., the best-fitting set of probabilities P_i for a given set of factor-groups and factors. For a given factor, i, if $P_i > 0.5$, that factor favors application of the rule. If $P_i < 0.5$, then factor i disfavors the application

[12] Interviews were conducted by Sharon Ash, Ann Bower, Surendra Gambhir, Wendell Harris, and myself. A considerable debt is here acknowledged both to the other interviewers and to the speakers who have shared a part of their lives with us in this form. The British speaker's material was taken not from a sociolinguistic interview but from the question-answer session after a paper presented at linguistics conference in the Southern United States. This is somewhat comparable in style to the other interviews, since it was neither casual speech nor reading-style speech, but an in-between "careful" style (cf., Labov's classification of speech styles, 1966).

[13] Programs implementing variable-rule analysis were used in two forms. Preliminary work used GoldVarb 1.0, written by David Sankoff and Pascale Rousseau; this varbrule program runs on the Apple Macintosh computer. Later work used variable-rule programs written by Susan Pintzuk, based on programs by Don Hindle and on algorithms and programs written by David Sankoff and Pascale Rousseau.

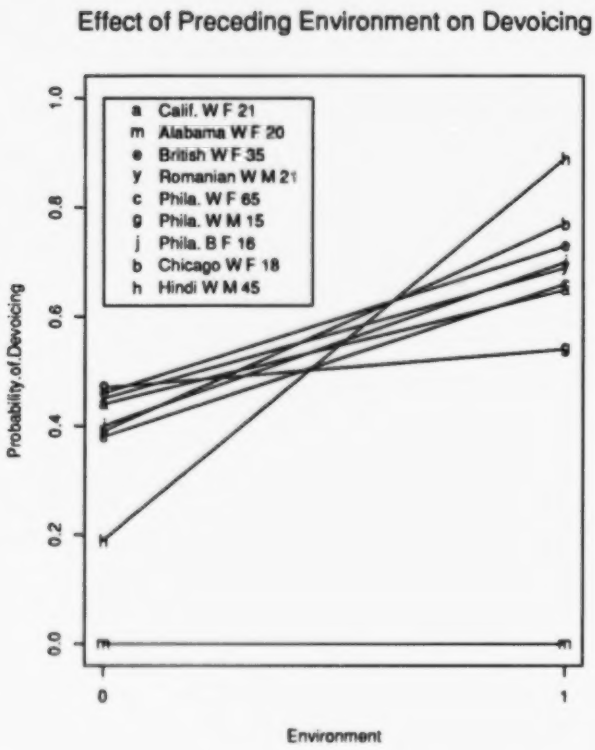

Figure 1: 0: Vowel, 1: Voiced Consonant.

of the rule. The closer to 1 or 0, the more that factor favors or disfavors rule-application.

5 Results:

5.1 Speakers Considered Separately

The first task is to see if the different speakers patterned the same way or not. If final devoicing is a pan-English phonetic process, the different speakers' devoicing patterns should be similar to each other. Because there were not enough tokens to fill out all the combinations of the different factors for each speaker, the environmental factors were collapsed into just three: voiceless consonants, voiced consonants, and vowels. Since underlyingly voiceless consonants do not precede final voiced fricatives in English, the preceding environments were reduced to only two: (voiced) consonants versus vowels.

Variable-rule analysis gives us the "probabilities" presented in Figures 1 and 2 and below in Table 1.

Figures 1 and 2 show how the effects of preceding and following environments for our 8 speakers. In Figure 1, the speakers are generally similar; there is a moderate increase in likelihood of devoicing associated with a preceding consonant as opposed to a preceding vowel (except the Hindi speaker, whose behavior is much more categorical, and the Alabama

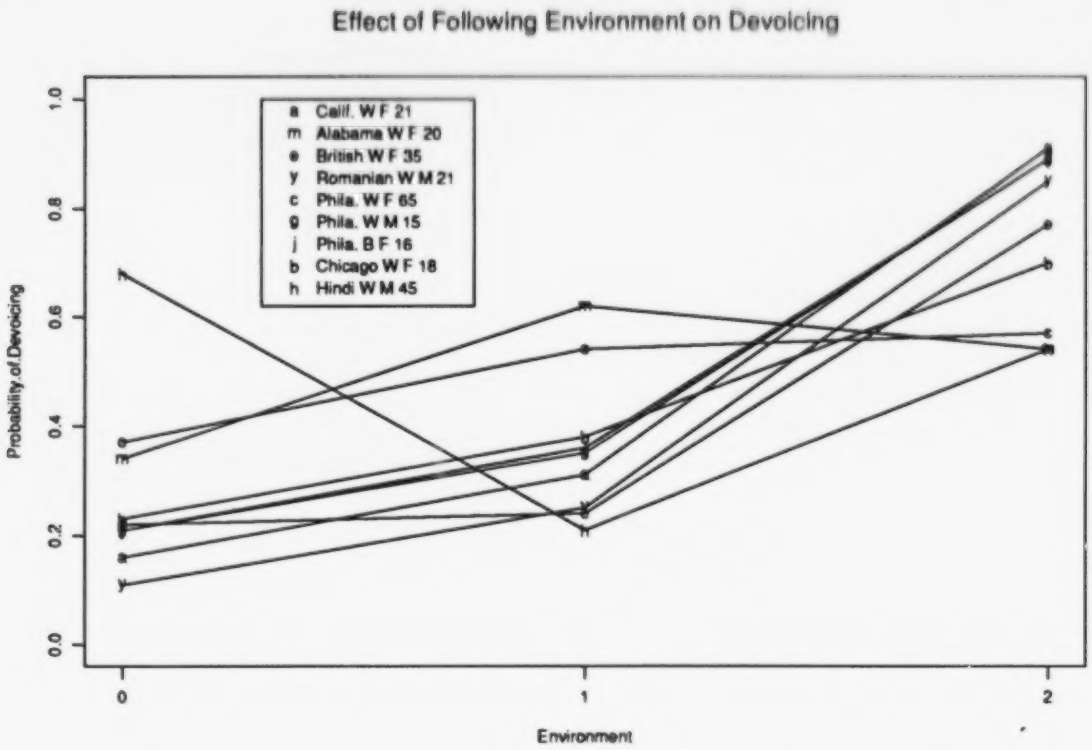

Figure 2: 0: Vowel; 1: Voiced Consonant; 2: Voiceless Consonant.

speaker, for whom there was insufficient data).

In Figure 2, the effects on devoicing of the voicing and consonantality of a following segment by different speakers are shown. Again, most of the speakers are very similar: There is a moderate rise between vowels and voiced consonants, and a much larger increase between voiced and voiceless consonants. Thus main effect is that of voicing; vocalicity has a weaker effect. In this graph, besides the Hindi speaker, 2 speakers stand out.

The anomalous speakers in Figure 2 are two, namely the two white female speakers from Alabama and Philadelphia. These are the two speakers with the highest overall rate of devoicing, with 84% and 89% overall devoicing respectively. Due to this high rate of devoicing, the number of voiced tokens is very small (totals of 9 and 16 tokens), with the result that the distribution of voiced tokens in the various environments may be strongly effected by chance. Therefore the pattern of environmental effects for these speakers may not be as different from that of the others as they seem in this graph.

Devoicing was found to occur in the speech of all these speakers. Therefore it is very likely that final devoicing of voiced fricatives is a pan-English phenomenon.

Finally, in this data, it appears that the segmental conditioning of final devoicing can differ across dialects or languages.[14]

[14]The Rumanian speaker does not stand out from the native English speakers in most of these measures,

5.2 Similar Speakers Together

The next task is to try to build up a more detailed picture of the conditioning pattern.

Pooling our 8 speakers' data, the resulting larger number of tokens (840), allows us to divide the environments into smaller classes without finding gaps in the pattern. The results of this larger analysis are summarized segment-by-segment in Table 1, and feature-by-feature in a variable phonological rule in Rule 1. Table 1 lists together phonetically related phonemes which could not be distinguished by a chi-square significance test. Phonetically unrelated phonemes which could not be statistically differentiated are listed separately and jointed annotated as Not Significant (N.S.). Thus, while each listed probability is only an estimate of the true probabilistic effect, the differences between the sets of segments in each factor group are all pairwise significant with $P < 0.05$. On the other hand, the patterns of the different segments within a group are not significantly different at this level, and may reasonably be grouped together.

The internal factors in Table 1 are three: the phoneme itself, the preceding phoneme, and the following phoneme.

First, the character of the fricative phoneme itself has a considerable influence on the level of devoicing. /v,ð/[15] strongly disfavor devoicing. That is, all else being equal, these weak fricatives will relatively rarely get devoiced as compared with /z,j/. The increasing level of devoicing from /v,ð/ to /z,j/ is similar to that found in Haggard, 1978, in whose data /j/ was more frequently devoiced than /z/, while both were much more frequently devoiced than the weak fricatives /v,ð/. In the current data also, /j/ seemed to favor devoicing slightly more than /z/, but the difference was not significant, while the difference between /z/ and /v,ð/ was highly significant. This pattern confirms Haggard's findings. As stated above, it is clear that /j/ devoices vigorously, with a frequency similar to or greater than that of /z/-devoicing. This may be taken as support of the decision to include /j/ in

although of all the speakers, the effect of a following vowel most categorically inhibits devoicing in his speech. The fact that he follows the pattern of the native English speakers in most features may be ascribed on the one hand to his fluency in English or on the other hand to the presence of the same pattern in his native language. The latter seems more likely, considering my impression that his speech contains considerable assimilatory voicing as well as devoicing, unlike that of the native English speakers. Thus his voicing assimilation behavior in general does not seem very similar to that of the native English speakers; these may be due to his native language. If this pattern is also found in Rumanian, it may also be asked, What other languages of the world have voicing assimilation (as opposed to assimilation only of voicelessness)? Or indeed, is voicing assimilation a universal phonetic phenomenon?

[15]The symbols for underlying segments used here, which are in some cases idiosyncratic, are exemplified by words in the following table. Each segment is exemplified by a word which contains it.

p	pip	t	tit	č	church	k	kick
b	bib	d	did	j	judge	g	gig
f	fizz	θ	thistle	s	sauce	ʃ	ship
v	Veatch	ð	this	z	zip	ʒ	usual
m	mum	n	none	ŋ	hung	h	hug
w	way	l	lay	r	ray	y	yay
uw	Boo!	ʊ	book	I	bid	iy	bee
ow	doe	ɔ	begat	ɛ	bed	ey	bay
aw	bough	ʌ	buck	æ	bad	ay	buy
ɔ	law			ɑ	cod	oy	boy

Estimated Probability	Factor
	Voiced underlying fricative phoneme:
0.14	/v,ð/
0.57	/z,j/
	Preceding phoneme:
{ 0.12	/uw/
N.S.{ 0.19	/æ,ɔ,a/
0.46	/iy,ey,oy,ow,ɪ,ɛ,ə,ay/
0.65	/m,n,ŋ,v,ð,b,d,g,r,l/
	Following phoneme:
0.16	/ɪ,ey,ɛ,y,æ,ay,aw,ə,r/
{0.33	/b,d,g,m,n,ð,j,l,w/
N.S.{0.35	/a,ow/
{0.51	/h/
0.87	/f,θ,s,ʃ,p,t,k,č,pause/
	Speaker:
0.24	Phila WM 15, Jaipur WM 50
0.35	Cal. WF 21, Rom. WM 21, Phil BF 17
0.60	Chicago WF 18, Britain WF 35
0.95	Birm.AL WF 19, Phila WF 65
0.49	estimated input probability.
	Total Chi-Square: 107.125
	Chi-Square/Cell: 1.530
	Number of Tokens: 840

Table 1: Variable-Rule Analysis Results for Final Fricative Devoicing

this study.

How can we explain the difference between weak and strong fricatives in their effect on devoicing?

Consider a physical explanation. The air-pressure between the constriction point and above the glottis has an inverse relationship to the pressure drop across the glottis (if subglottal pressure is held constant): the higher the supra-glottal pressure, the smaller the pressure differential across the glottis. This pressure differential across the glottis is necessary for continued voicing.

The greater noise-producing efficiency and smaller oral constriction associated with the strident (af-)fricatives results in a greater obstruction of airflow. In conjunction with a constant subglottal pressure, strident fricatives should have greater air-pressure behind the constriction and thereby a weaker pressure differential across the glottis than weak fricatives.

Weak fricatives on the other hand have a more open constriction and less noise-producing efficiency, resulting in less obstruction of airflow. (Also, in the case of /v,ð/, a slightly larger cavity between the glottis and the point of constriction than for /z,j/ requires greater glottal airflow to produce the same air pressure behind the constriction). All these physical factors tend in the same direction, namely that — all else being equal — the pressure behind the constriction should be higher during strident fricatives, resulting in a weaker pressure drop across the glottis and increased difficulty in maintaining vocal-fold vibration. This would result in a greater likelihood of devoicing for strident as compared with weak fricatives.

Beyond these physical factors, another observation seems to point to a better explanation of the difference between weak and strong fricatives in their effect on devoicing. Lisker et al. observe observe that "almost exclusively, the [phonologically voiced] fricatives with higher levels of noise intensity, primarily /z/ and /ʒ/, show opening of the glottis as the normal accompaniment of the oral constriction." That is, the phonologically voiced weak fricatives /v,ð/ did NOT normally show glottal opening. Glottal opening is inversely correlated with vocal-fold vibration: When the vocal-folds are widely separated, they do not vibrate as easily; they vibrate best when nearly closed. Thus /v,ð/ would appear to avoid devoicing due to continued laryngeal adduction. This answer begets another question: What is the reason for this difference in laryngeal behavior among voiced fricatives?

It would appear that the weak-strong distinction among fricatives is based not only on differences in the degree of constriction and in the noise-producing efficiency of different constrictions, but also on the lesser or greater degree of glottal opening which accompanies the constrictions. These factors tend in the same direction. Since laryngeal adduction is under relatively direct motor control, the explanation suggested by Lisker's observation points to differences in laryngeal control strategies for weak and strong fricatives despite their shared phonological voicing status. It would appear that the linguistic control mechanism has exaggerated the physical differences by differentially adducting the larynx. This may be taken as evidence that weak fricatives not only devoice less often than strong fricatives, but further, if voicing status may be measured by glottal adduction, weak phonologically voiced fricatives are at some level of the linguistic production system, *more voiced* than strong phonologically voiced fricatives.

The second factor group in Table 1 is the preceding environment. The preceding phoneme has a clear and statistically significant effect on the likelihood of devoicing. The preceding-segment effects shown in Table 1 may be arranged in a hierarchy where devoicing

is favored least by /uw/, and increasingly by low vowels, other non-low vowels, and (voiced) consonants.

The low vowels (/æ/ as in "ax", /ɔ/ as in "ought" and /ɑ/ as in "ox") strongly disfavor devoicing. The remaining non-low vowels slightly disfavor devoicing. Preceding voiced consonants rather strongly favor devoicing. And underlyingly voiceless consonants, since they do not occur in this position, could not be examined.

The general picture is that the degree of openness of the vocal tract in a preceding segment is inversely correlated with the likelihood of devoicing. Thus if the preceding segment is more open, then a phonologically voiced fricative is less likely to be devoiced. Two exceptions should be noted. One clear exception to this principle is the vowel /uw/ as in "bruise".[16] Fricatives never devoiced after /uw/ unless they also occurred before voiceless consonant or pause (which strongly favor devoicing). Since /uw/ is a high vowel, the proposed principle predicts wrongly that devoicing should occur more often after /uw/ than after other more open vowels. Instead, /uw/ seems to act like a low vowel in this data. It may be possible to attribute this mismatch to chance, since the number of cases is fairly small; also the solution may have something to do with vowel length or complexity, since /yuw/ is one of the more complex glides of English.

The second, only apparent, exception is the glide, /ay/, as in "five" or "guys". This vowel does not pattern with the low vowels, but with the non-low vowels. Since it is the glide rather than the nucleus of this vowel that is actually adjacent to the fricative, and since the glide is not low, this explains why this diphthong does not pattern with low vowels despite its low nucleus. Such an explanation suggests that if devoicing is to be expressed in a phonological rule, the rule should be sensitive not to the height of the adjacent vowel nucleus, but rather to the height of the adjacent vocalic segment irrespective of whether it is a nucleus or glide. This is not then an exception to the pattern, but confirmation of it.

Thirdly, the voicing and vocalicity of following segments has a strong effect on final fricative devoicing. The primary distinction to be made is that of voicing, since the voiced consonants are considerably more similar to the vowels than to the voiceless consonants. So the most important effect is that voiceless following segments (including pause) strongly favor devoicing. Following voiced segments, which disfavor devoicing, are divided into vowels and consonants, where consonants favor devoicing more than vowels.[17]

This general picture has some further details which must be noted. First, two of the vowels, /ɑ,ow/ were not statistically distinguishable from the voiced consonants; they favored devoicing of the adjacent fricative significantly more than the other vowels. Explanation for this anomaly awaits further research.[18] Secondly, while word-initial /h/ is certainly a

[16] In 16 of its 21 occurrences in this data, the vowel was preceded by a /y/-glide, as in "use", "huge", etc.

[17] If more data were available, it is possible that these three categories might be subdivided into a finely graded continuum of following environments, each point of which could be statistically distinguished from each adjacent point. Preliminary versions of this work showed a finely graded hierarchy of environments where devoicing was more and more likely before a following vowel, nasal, voiced fricative, voiced stop, voiceless stop, pause, and most before a voiceless fricative. However the finer subdivisions within the voiced and voiceless consonants were not statistically significant. A greater amount of data might give significance to such a finely graded hierarchy.

[18] In most (28 of 39) of the relevant tokens (those in which the target fricative was followed by one of these vowels), the vowel was followed by one of /l,n,r/, three segments whose effects on preceding vowels can be very strong. It is conceivable that the resonant after the vowel had some effect on the vowel, and thereby exerting an influence on the devoicing of the preceding fricative, making the vowel more like a voiced consonant in its effect. Such a possibility is intriguing, but mysterious.

voiceless consonant underlyingly, it is nevertheless very often phonetically absent. /h/ is frequently deleted in all these dialects.[19] With no surface [h] in these cases, the subsequent segment is actually a vowel, which would strongly disfavor devoicing. This accounts for the anomalous behavior of /h/, which does not pattern with the other voiceless consonants. The phonological conclusion is that /h/-deletion precedes fricative-devoicing. The methodological conclusion is that the surface phonetic form of adjacent segments may be more important than the underlying phonological features in the environment. It is suggested that further research on this variable should take into account the phonetic environment as well as the phonological environment.

A variable phonological rule may be written which summarizes this pattern of internal effects on devoicing:[20]

$$\begin{bmatrix} +fric \\ +voice \end{bmatrix} \rightarrow [-voice] \; / \left\{ \begin{array}{l} [-voc]\,(.65) \\ \left[\begin{array}{l} +voc \\ -low \end{array} \right](.46) \\ \left[\begin{array}{l} +low \\ +voc \end{array} \right](.19) \\ /uw/(.12) \end{array} \right\} \left\{ \begin{array}{l} [+\overline{strid}]\,(.57) \\ [-strid]\,(.14) \end{array} \right\} \left\{ \begin{array}{l} \$ \\ \# \end{array} \right\} \left\{ \begin{array}{l} [-voice^{21}]\,(.87) \\ /h/(.53) \\ \left[\begin{array}{l} +voice \\ +cons \end{array} \right](.33) \\ /\text{ɑ},\text{ɔ}/(.35) \\ [+voc]\,(.16) \end{array} \right\}$$

Finally, each speaker's overall tendency to devoice these fricatives is encoded by the Speaker factor group. Under the Speaker heading in Table 1, we see that the general level of devoicing varies widely. These numbers show only that dialect differences are not obvious within this group of six speakers. The Philadelphian whites, who might be expected to be the most similar pair of speakers, are in fact at opposite ends the spectrum, thus the dialect(s) of even a single city may encompass the full range of devoicing frequencies. It may be interesting to note that the three men in the study were at the low end of the scale. This could correlate with greater use of breathy voice by women in general, or could be an artefact of the small sample. While this sample is too small to show whether the individual differences found are to be attributable to dialect differences, it is clear that all of these representatives of various English dialects do produce phonologically voiced final fricatives which are phonetically devoiced; therefore final-fricative-devoicing appears to be a pan-English phenomenon.

6 Conclusion

This impressionistic study of speakers of a range of English dialects has investigated some influences on the pattern of phonetic final devoicing of phonologically voiced fricatives and

[19] Thus this phenomenon is much more widespread than the British "Cockney" dialects which it is a highly stereotyped feature.

[20] The use of a categorical feature [-voice] here is somewhat misleading, since partial devoicing is part of the phenomenon studied here.

affricates. It found considerable agreement between impressionistic classification by the author and spectrogram examination. In agreement with Haggard (1978), it was found that the strong fricative and affricate /z,j/ devoice more than the weak fricatives /v,ð/; that preceding segments favor devoicing in a hierarchy (increasing) from low vowels to other vowels to (voiced) consonants; that following segments favor devoicing primarily according to their underlying voicing, and secondarily according to whether the (voiced) segment is vocalic or consonantal. Differences among speakers in overall likelihood of devoicing did not appear to be attributable to regional dialect differences; we conclude that final devoicing of phonologically voiced fricatives is a pan-English phenomenon.

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